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Screening of Arjun (*Terminalia arjuna*) Accessions based on Drought Tolerance Indices under various Environmental conditions

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ABSTRACT: Tasar silkworm (*Antheraea mylitta*) primarily feeds a dozen of food plants. Of which, Arjun (*Terminalia arjuna*) is a major food plant growing largely in rainfed condition. Often, the Arjun plant is growing under water stress condition during most part of the growing period causes considerable reduction in leaf quality and yield which in turns to affect the Tasar cocoon quality and yield. With the aim of screening the most potential accessions of arjun *(Terminal arjuna*) plant for drought environmental conditions, a study was conducted in factorial experimental design under two stress environmental conditions *i.e*., stress and non-stress in 2016-2018. Nine different drought tolerance/resistance indices comprising stress tolerance index (STI), mean production (MP), geometric mean production (GMP), tolerance index (TOL), stress susceptibility index (SSI), yield stability index (YSI), relative drought index (RDI), drought resistance index (DI) and yield index (YI) were evaluated on the basis of leaf yield in two environments i.e., irrigated and drought. The results revealed that leaf yield of Arjun plant under stress and non-stress environment was found significant and it was positively correlated with MP, STI, GMP, YSI, TOL, RDI, DI and YI, and negative correlation found with SSI. Based on the ranking method, the accessions 525, 123, 135 and 523 are most suited for drought environments. Eventually, this experiment results confirmed that drought tolerance indices such as MP, STI, GMP, YSI, TOL, RDI, DI and YI could be considered as the most suitable indices for evaluating drought tolerant accessions. Therefore, this study recommends that the accessions 525, 123, 135 and 523 were showed highest degree of tolerance to drought and can be used in future breeding studies in order to develop high yielding under drought environmental conditions.

Keywords: Drought, Indices, Ranking, Tasar, *Terminalia arjuna.*

INTRODUCTION

Arjun (*Terminalia arjuna*) is one of the most important food plants for tasar silkworm (*Antheraea mylitta*) in which its leaf yield is on average 3 to 5 kg/ha. The Arjun plant is widely distributed over India. Tasar silkworm feeds a dozen of plant species of different families; however, it favours the leaves of *T. tomentosa* (Asan), *T. arjuna* (Arjun) and *Shorea robusta* (Sal) and are believed as primary food plants. India is the only land producing all the five industrially developed silks namely Mulberry silk, Eri, tropical and temperate/Oak Tasar and Muga silk. Of which, Tasar silk is mainly produced in many Indian states like Jharkhand, Chhattisgarh, Odisha, West Bengal, Andhra Pradesh, Telangana and Maharashtra. Tasar sericulture has huge potential of providing employment opportunities to a great tribal population with little investment. Around 3.0 lakh families, mostly tribals, are dependent on the industry (CSB, 2017).

The Arjun plant is widely grown as rainfed in arid/semi-arid regions since an immense variation is common in the rainfall distribution and quantity in different years and places (Kirigwi *et al*., 2004). Jaleel, (2007) reported that abiotic stresses *viz*., thermal, moisture and salt stress are the major reasons of crop failure globally which plunges agricultural productivity by more than half. In arid and semiarid regions of India such Jharkhand, Chhattisgarh, Odisha, Maharashtra and Telangana States arjun plants usually encounter various biotic and abiotic stress conditions during the rearing period. Therefore, silk production reliant on arjun plants and its potentiality are mainly governed by moisture stress which leads to decline in the yield of tasar silk cocoon. Among them which affect and decline arjun plant leaf yield, 25-30 percent belong to drought stress. The main issue of producer of tasar silk is leaf yield loss in arjun plant and consequently, they accentuate on performance of leaf yield in stress environment. Screening of drought tolerance is difficult owing to the phenomenon of complex relationship between accessions of arjun and surrounding ecology. There is limited information regarding the function and mechanisms of tolerance. Different methods have been used by many scientists to assess genetic variation in drought tolerance. The vital appraise for selection under drought situation is able to screen the accessions with an enviable as well as comparable less variation yield under two different environments i.e., stress and non-stress (Mitra, 2001). Besides, the preeminent indices are with highly positive correlation in relation to leaf yield under both environments. Therefore, different indices have been used to screen out the drought tolerant accessions based on the yield loss in drought in contrast to stress free conditions. Numerous assortment measures have been suggested for screening the accessions depending on their performance in stress and stress-free situations. Blum, (1988) stated that screening of accessions for drought tolerance must be related to high yield under stress free conditions. Mitra, (2001) has used different Indices of drought based on yield loss in stress over stress free environments for selecting drought tolerant genotypes. Several drought tolerance selection indices as mentioned in Table 1 were employed to screen the drought tolerant accessions. This experiment was carried out in order to assess different arjun accessions response to drought/ moisture stress. Also, this study aims to find out the best measures for increase and improvement of accession leaf productivity under stress and non-stress environments. Besides, this trial was conducted to evaluate the selection criteria for screening drought tolerance in arjun accessions. Therefore, viable drought tolerant accessions can be recommended for growing in drought prone regions of tasar sericulture regions.

Table 1: Drought resistance indices were calculated using the following relationships.

Index name	Equation	References
Stress Tolerance Index	$[(Yp) \times (Ys)] / (\bar{Y}p)^2$	Fernandez, (1992)
Mean Productivity	$(Yp + Ys) / 2$	Rosielle and Hamblin, (1981)
Geometric Mean Productivity	$[(Yp) \times (Ys)]^{0.5}$	Kristin *et al.* (1997)
Stress Tolerance	$(Yp - Ys)$	Rosielle and Hamblin (1981)
Stress Susceptibility Index	$[1-(Ys/Yp)]/[1-(\bar{Y}s/\bar{Y}p)]$	Fischer and Maurer (1979)
Yield Stability Index	Ys / Yp	Bouslama and Schapaugh (1984)
Relative Drought Index	$(Ys / Yp) / (\bar{Y}s / \bar{Y}p)$	Fisher and Wood (1979)
Drought Resistance Index	$Ys \times (Ys / Yp) / \bar{Y}s$	Lan, (1998)
Yield Index	$YI=(Ys)/(\bar{Y}s)$	Gavuzzi *et al.* (1997)

MATERIALS AND METHODS

The research experiment was carried out at Central Tasar Research and Training Institute (CTR&TI), Ranchi, Jharkhand State, India (latitude 22°30′N, longitude 85°.06′E, Altitude 651 m above mean sea level). The climate of the site is characterized by maximum and minimum temperature ranges from 29.3°C to 41.7°C and from 4.5°C to 19.8°C, respectively. The mean annual rainfall during the trial period was 1320 mm. The ten most superior accessions of *Terminalia arjuna* were selected in the study for collection of cutting propagules during the rainy season (Table 2). Arjun plant saplings were raised through propagation of Juvenile and leaf node cuttings from 1-2 months old branches of the mother plants. The saplings were allowed to grow in earthen pots for one year. After one year of growth, the saplings were used for further experimental study i.e., drought tolerant study. Drought tolerant treatments study included control and stress treatments. In both treatments, water was fully supplied during the sapling and growth periods to keep the plants growing under well-watered conditions. Thereafter, water supply has been withdrawn and the saplings were allowed to wilt, subjected to water stress in the stress treatment. In case of control treatment, plants of all accessions were maintained with ideal soil moisture throughout the study period. Experiments were terminated after fourteen days of water stress. All experiments were conducted under a controlled environment in a greenhouse. At the final stage, leaf yield from stress (Ys) and non-stress conditions as potential yield (Yp) were recorded.

Table 2: Accessions of arjun used for drought tolerance evaluation.

Accession No.	Native of Accession
718	Orcha, Madhya Pradesh
135	Sundargarh, Odisha
102	Gadchiroli, Maharashtra
115	Haldi, Uttarakhand
123	Ranchi, Jharkhand
614	Kametya Pauri, Garhwal, Uttarakhand
525	Medak, Andhra Pradesh
507	Ranka Garwah, Jharkhand
523	Purniyadeeh, Palamu, Jharkhand
424	Haridwar, Uttarakhand

As mentioned in the above formulas, Ys indicates yield under stress, Yp means yield under non-stress for each accession, Ys is yield mean in stress, and Yp is yield mean in non-stress conditions for all accessions. Correlation between different drought indices and leaf yield in two different environments were done by using SPSS ver. 16.

RESULTS AND DISCUSSION

A. Evaluation of accessions based on the indices

In the study, various indices were computed based on the leaf yield of *T. arjuna* in two different moisture environments i.e., stressed and non-stressed conditions to explore the appropriate indices of drought tolerance for selecting *T. arjuna*. The evaluations of stress tolerance features showed that the explorations of drought tolerant accessions through a single criterion was contrary. Dabiry *et al*., (2015) also reported that identification of drought tolerant genotypes based on single criterion was contradictory. According to the stress tolerance index (STI), the Accn 523 and 525 were significantly observed to have the highest STI in stressed environments while, the Accn 614, 718 and 424 exhibited the least value of STI in stressed conditions (Table 3). Accn 135 and 123 had shown under mild water stress conditions. Khodarahmpour *et al*. (2011); Khalili *et al*. (2012) corroborated STI and GMP indices could be the more accurate criteria for selecting the high yielding accessions for drought conditions. Similarly, the highest MP and GMP were shown in Accn 523 and 525 under stressed conditions. The lowest MP and GMP were observed in Accn 614 under severe stressed conditions. Under mild stress environments, the highest and lowest GMP and MP were found in the accessions (135 and 123) and (718 and 424), respectively. So, according to TOL and SSI indices selected the 'Accn 123 followed by 135, 102, 525 as the most relatively tolerant accessions while for TOL, the Accn 424, 507, 614 and 718 and for SSI, the Accn 424 followed by 614, 507and 718 were relatively lowest tolerant. Based on YSI and RDI, there was no significant difference found among all the accessions. Based on these indices, Accn 123, 135, 525 and 102 were found as the relatively drought tolerant accessions while Accn 424 followed by 614, 507 and 718 were the lowest amount of YSI and RDI under water stress conditions. Based on DRI, under stressed conditions, the most tolerant accessions were Accn 525 which is statistically at par with 123, 135 and 523. A significant least DRI was observed with Accn614, 424 and 718. Similarly, based on the yield index (YI), the Accn 525, 523,123 and 135 were the most prominent accessions under stressed conditions. Accn:614 followed by 424 and 718 were the least YI under severe drought stressed conditions.

Table 3: Variability of different drought tolerant indices for different *T. arjuna* accessions as a function of non-stress and drought stress under controlled environment condition.

Accessions	STI	MP	GMP	TOL	SSI	YSI	RDI	DRI	YI
718	0.645	159.8	158.4	40.10	1.063	0.778	0.985	0.700	0.898
135	0.966	194.6	193.8	32.64	0.733	0.848	1.075	0.973	1.146
102	0.805	178.1	177.2	32.84	0.799	0.832	1.054	0.863	1.037
115	0.821	179.8	178.9	34.96	0.828	0.824	1.043	0.859	1.042
123	0.962	194.2	193.6	29.28	0.652	0.861	1.089	0.992	1.152
614	0.563	149.8	148.2	43.61	1.208	0.744	0.942	0.611	0.818
525	1.017	200.0	199.2	33.68	0.738	0.845	1.070	0.994	1.175
507	0.825	181.2	179.5	49.85	1.143	0.759	0.961	0.761	1.002
523	1.028	201.4	200.2	41.89	0.884	0.813	1.029	0.942	1.158
424	0.657	162.4	159.7	56.96	1.424	0.704	0.893	0.614	0.863
SE	*0.013*	*1.409*	*1.403*	*2.587*	*0.056*	*0.011*	*0.015*	*0.018*	*0.011*
LSD	*0.038*	*3.975*	*3.958*	*7.298*	*0.159*	*0.033*	*0.042*	*0.052*	*0.030*

STI: Stress Tolerance Index; MP: Mean Productivity; GMP: Geometric Mean Productivity; TOL: Stress Tolerance; SSI: Stress Susceptibility Index; YSI: Yield Stability Index; RDI: Relative Drought Index; DRI: Drought Resistance Index YI: Yield Index

B. Correlation between leaf yields and drought tolerance indices

To select the best suitable criteria of drought tolerance, the correlation coefficients were cal- culated for the indices among Ys, Yp and other quantitative drought tolerance indices. In other words, correlation analysis between leaf yield and drought tolerance indices could be a desirable measure for identifying the suitable accessions and indices used. Mitra, (2001) suggested a selected indices must have a significant correlation with leaf yield in two environmental conditions. In the present investigation, indices such as MP, STI and GMP with Yp and between YI and Ys showed a significant and positive correlation whereas a higher degree of negative correlation was observed between SSI and yield under stress environment (Table 4). However, Ehdaie and Shakiba (1996) observed that correlation between stress susceptibility and yield was not exhibited in ideal conditions. The indices such as STI, GMP, MP, TOL, YSI, RDI, DI and YI showed a significant and positive correlation with leaf Yield under stress condition (Ys). Similarly, the indices such as STI, MP, GMP, DRI and YI had significant and positive correlation with leaf yield in non-stress condition (Yp); it representing that these parameters were more effective in screening high yielding accessions in different moisture conditions. The findings of this experiment showed there existed a significant and positive correlation for STI, MP and GMP with Yp and between YI and Ys. Albeit, there was significant and negative correlation found between SSI and leaf yield in a stress environment. Toorchi *et al.* (2012) observed a positive correlation between GMP, MP, Yp and Ys. Khalili *et al.* (2012) found a significant and positive correlation for GMP, MP and STI with stress yield. Our results were confirmed with results of Golabadi *et al*. (2006). Mehrabi *et al*. (2011) reported GMP and STI could be effective indices for screening high yielding drought tolerance corn hybrids. Aghaei *et al*. (2017) reported that correlation between different traits can be used as good indicator to select the drought tolerant genotypes. Jafari *et al*. (2009) also found that STI and GMP indices were used as most potential for maize breeding programs to identify drought tolerant hybrids since they exposed the greatest correlation with yield in both stress and non-stress environments. Our study indicated that indices such as STI, GMP, MP, TOL, YSI, RDI, DI and YI among drought tolerance indices may be used as the most potential and ideal gauges for selecting drought tolerant accessions of *T. arjuna* due to positively exhibited greater correlation with Yp and Ys. This result was also confirmed by Farshadfar *et al.* (2001).

Table 4: Correlation coefficients between drought tolerance indices and leaf yield under water deficit and well-watered conditions.

	Yp	Ys	STI	MP	GMP	TOL	SSI	YSI	RDI	DRI	YI
Yp	1										
Ys	0.92**	1									
STI	0.97**	0.99**	1								
MP	0.97**	0.98**	1.00**	1							
GMP	0.97**	0.99**	1.00**	1.00**	1						
TOL	-0.30	-0.66*	-0.54	-0.52	-0.54	1					
SSI	-0.59	-0.87**	-0.78**	-0.76*	-0.78**	0.95**	1				
YSI	0.60	0.87**	0.78**	0.77**	0.78**	-0.94**	-1.00**	1			
RDI	0.60	0.87**	0.78**	0.77**	0.78**	-0.94**	-1.00**	1.00**	1		
DRI	0.84**	0.99**	0.95**	0.94**	0.95**	-0.77**	-0.93**	0.94**	0.94**	1	
YI	0.92**	1.00**	0.99**	0.98**	0.99**	-0.66*	-0.87**	0.87**	0.87**	0.99**	1

* and ** Significant at the 5% and 1% levels of probability, respectively

Ranking System. The evaluation criteria of drought tolerance showing that the selection of drought tolerant accessions by using a single measure may be contrary. To screen the most suitable drought tolerant accessions consistent with the all indices, mean rank and standard deviation of ranks of all drought tolerance criteria were calculated and according to these both criteria, the most suitable drought tolerant accessions were selected. In consideration to all indices, accessions 525, 123, 135 and 523 revealed the superior mean rank and nearly lower standard deviation of rank; therefore, these accessions known as the best drought tolerant accessions, and accessions 614, 424 and 718 found as the highly sensitive (Table 5). These findings were confirmed with the results of Farshadfar *et al.* (2012); Khalili *et al.* (2012).

Table 5: Rank, rank mean ($\bar{R}$) and standard deviation of ranks (SDR) of drought tolerance indices.

Accessions	STI	MP	GMP	TOL	SSI	YSI	RDI	DRI	YI	$\bar{R}$	SDR
718	9	9	9	6	7	7	7	8	8	7.78	1.09
135	3	3	3	2	2	2	2	3	4	2.67	0.71
102	7	7	7	3	4	4	4	5	6	5.22	1.56
115	6	6	6	5	5	5	5	6	5	5.44	0.53
123	4	4	4	1	1	1	1	2	3	2.33	1.41
614	10	10	10	8	9	9	9	10	10	9.44	0.73
525	2	2	2	4	3	3	3	1	1	2.33	1.00
507	5	5	5	9	8	8	8	7	7	6.89	1.54
523	1	1	1	7	6	6	6	4	2	3.78	2.54
424	8	8	8	10	10	10	10	9	9	9.11	0.93

CONCLUSION

The results of this study concluded that all indices of drought tolerance and resistance except RDI and YSI showed highest correlation with leaf yield in both stress and non-stress environments representing great suitability of these indices for identification of tolerant accessions. Identifying drought tolerant accessions based on ranking method indicated accessions 525, 123, 135 and 523 as the best drought tolerant. Hence, it could be recommended as used as parents for breeding of drought tolerance in the desired accessions. Besides, this study revealed that among drought tolerance indices MP, STI, GMP, YSI, TOL, RDI, DI and YI can be used as the best suitable criteria for selecting drought tolerant accessions for *T. arjuna*.

FUTURE SCOPE

The selected accessions i.e., 525, 123, 135 and 523 from this study can be used as genetic stock for further improvement and development of drought tolerant varieties of Arjuna plant. These accessions can be certainly helpful for achieving sustainable Tasar sericulture production and sustenance the farmers' socio-economic status.

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Conflict of Interest. None.

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